Quantum Computing - Small Science, Huge Opportunity

Ben Kingsley	Hello, I'm Ben Kingsley and I'm joined by Emily Bradley and Natalie Donovan for the third in this series of podcasts. After the first session where we looked at some of the basics of quantum computing, in our second podcast, Rob Sumroy talked to Robert Hannagan and Dr. Ali Kaafarani about security and encryption issues, and they ended with some practical recommendations about the ways businesses might now start to make preparations in anticipation of a world in which quantum computing exists. So in this final session, we are going to bring the topic perhaps a little closer to home by thinking about ways in which business and other enterprise might now start to get involved with quantum computing, and to bring some colour to that discussion we spoke to Alexei Kondratyev who is Head of Innovation and Data Science at Standard Chartered Bank. We asked him to share some of his experiences and recommendations from working with quantum computing in the financial services industry. One of the first questions we posed to Alexei was why a business such as Standard Chartered might want to get involved with an experimental technology like quantum computing.
Alexei Kondratyev	It's such a powerful new technology and there is now a history of technological disruption when you look back to the middle of 20th Century when classical digital computing completely disrupted our lives and then we look at internet that also completely disrupts the way of the business and had massive impact on our society, and we can imagine that quantum computing, something that brings us almost infinite computing power, will have similar impacts on everything we do, then how can we not be engaged and how can we not try and be part of this new emerging eco-system.
Ben Kingsley	Ok that's interesting Alexei, so I suppose the chestnut question then as to at what point do you think we are likely to be seeing live fire operational deployment of quantum computing technology in businesses such as Standard Chartered?
Alexei Kondratyev	The promise is very fast. Looking back several years, we see enormous progress over the last two or three years, so if you would extrapolate into the future, and the growth is exponential, I think it's very reasonable to assume that in a couple of years, you will start seeing first real world productive deployment of quantum algorithms to actual business sponsors.
Ben Kingsley	..which is an interesting view on timescales isn't it Emily because we've heard quite a range of views as to the timeline for quantum computing becoming a reality.

Emily Bradley	Yes so some people we speak to seem to suggest it's about ten years don't they, but here Alexei is saying two years and he also highlighted what we've heard elsewhere that actually this timeline is dependent upon the fact that quantum will be accessed as a service over the Cloud, as opposed to individual businesses having their own quantum hardware.
Alexei Kondratyev	It's very likely that access to quantum hardware, quantum computing hardware, will be via a Cloud solution, we would access quantum computing via internet, we will send instructions over internet and we listen back results over internet because it's unlikely that a quantum hardware will become portable in the nearest future. They are talking about several years before quantum computing will be used for real world applications as a matter of course, but probably it's much, much longer in the horizon before quantum hardware becomes portable.
Ben Kingsley	Yes, ok, so I think what this means is that for the majority of businesses, we won't need to be concerned with the details of how quantum computers are built and accessed because that will be in the hands of a select group of quantum hardware developers and so for most businesses, it will be a matter of exploring and testing and developing ways of using the power of quantum computing as a service.
Emily Bradley	And given that we are talking about such short timescales before quantum could potentially be accessed as a service, it leads onto really interesting questions of the types of applications that might be of interest to businesses. We spoke to Alexei and he mentioned a couple of categories Standard Chartered is considering as an international financial institution.
Alexei Kondratyev	I would say that the range of possible applications falls into two broad categories. When we talk about quantum machine learning, we have two types of models which we can productively run on existing noisy, what you call, noisy intermediate scale quantum NISQ devices. So this fashion of loading models can be classified as generative models, models that would help to generate new samples from the loan distribution, you can imagine generating new images once you learned several categories. For example a model can learn cats and dogs and then it can generate pictures of new cats and new dogs – completely synthetic images. In finance we will learn a distribution of particular risk factors, assets and so on and then we will generate new samples from the distributions. Or there is a class of models called discriminative models, or classifiers, where the task is to classify a sample. So, you are presented with an image and then you decide whether it's a cat or dog, or in finance you can think

	about classifying an input as a bi-signal or cell signal, something like that. So these two types of models can be productively deployed on NISQ noisy intermediate scale quantum devices and we see first signs of quantum advantage here.
Ben Kingsley	So lots of cats and dogs there in the imagery but I think the core of what we are hearing, and we again hear this elsewhere, is that the problems that we expect quantum to be really good at solving our problems that involve complex modelling, advance modelling, and so naturally it's those sorts of modelling tasks that are the prime area for now for businesses to be investigating what quantum technology might do. Just before we delve a bit further into that thought I think it's worth us pausing on the piece of jargon that Alexei mentioned there – noisy intermediate scale quantum devices. Quite a mouthful but it's a term that gets used quite frequently in a space at the moment. Emily, why don't you tell us what that means.
Emily Bradley	Yes so sometimes it's referred to as the NISQ period and my understanding is that it's the period of quantum computing that we are currently in. So there are quantum computers that have already been built, but they are noisy, by which is meant that they suffer from some form of interference, they are sensitive to disturbance, and that makes them prone to error. But that's not to say that nothing can be run on them.
Ben Kingsley	Yeah, so really what we are saying is that at least for now, we are in a period where the technology is relatively in its infancy and so whilst we can harness some of its power to improve our abilities in some areas and we can see that over time there will be opportunities to harness more of that power, our ability to accurately model complex situations, for example, at the moment is still to an extent hampered by the immaturity of the hardware, and so our ability to create new applications and run new software is going to be relatively limited until we can overcome some of those issues. So let's come back to the topic of modelling, because that does seem to be an area where repeatedly we are hearing that quantum computing power presents some really meaningful benefits or gains over traditional computing power. Modelling of course is very much a feature of the financial markets, and I'm sure that's why Standard Chartered have an interest in it, but of course it's a feature of many industries when we think about the need to model chemical or human or vehicle movements or modelling efficiencies in industrial processes. It's tempting, isn't it, to think that based on what we've just said and heard, that quantum computing might be something that's reserved to solve the most complex of problems and situations that we face, whether it's in finance or biotech or any other

	industry, but I think Nat, it must also be the case that quantum computing has the potential to make incremental but potentially significant improvements to non-complex, or at least apparently mundane systems and processes right?
Natalie Donovan	Yes, I think that's right and as we've seen, while you can think of lots of complex modelling that a bank like Standard Chartered may want quantum to help with, as you mentioned, it may also be used to help bring efficiencies to quite laborious tasks that would take a classical computer a long time to work through in areas like logistics, for example.
Ben Kingsley	Yeah, and that's not just because there's more power in a quantum computer, if I can put it that way, but it's because of the very nature of a quantum computer, relative to a traditional computer.
Natalie Donovan	Yeah, I mean absolutely. A common example I have heard people use is describing how a computer would work out how to escape a maze, so a traditional computer would effectively work its way through every path until it found the one leading to the exit, whereas if you've got a quantum computer, it basically tries every path at once and manages the uncertainty that approach inherently brings with it, and I suppose I think of it as a kind of multi-tasking which I'm sure is not the correct technical term, but you can imagine how that could speed up and bring efficiencies to a whole range of business processes.
Emily Bradley	Yeah and I think that image of the maze is very effective isn't it, at capturing what's going on – I find that very helpful. So I suppose we have been speaking about some of the potential applications of quantum computing and the natural next step might be to think how businesses go about realising those opportunities. What we seem to have been hearing from our clients is that it's not that you've have to go and build, you know we spoke about this earlier, go and build your own quantum computer, but actually it's a more collaborative consortia based model, that really works, and this point about collaboration did come up when we were talking with Alexei
Alexei Kondratyev	I think it's a general industry trend or general situation where we have to collaborate. It's an area where we have completely different institutions working together bringing their own expertise in different areas, sometimes non-overlapping areas, as we discussed, we can have a financial institution, an academic institution, a hardware manufacturer, a software developer – very different companies from very different areas, but working together to achieve a common goal and building the whole eco-

	system around them. So I think it requires clearly different type of support and a different type of maybe even, different kind of agreement if you wish, so addressing all these issues is not an easy task, and I think that's exactly where companies like yours can help us and can help to design and develop new industry standards.
Natalie Donovan	As Alexei mentioned there, I mean collaboration is an area that we help clients with in a range of sectors and with a range of technologies, and there are obviously various ways you can collaborate. When we were speaking to Alexei about what Standard Chartered was doing in relation to quantum, he talked a little about how a consortia model works for them.
Alexei Kondratyev	Probably the most productive way forward is to have a consortium, that would combine a quantum hardware manufacturer, together with quantum software development companies, together with industry partners who can bring in various use cases, challenging interesting use cases but also provide a lot of expertise in several areas such as machine cloning, AI, and classical bench marking, so I think in this regard, financial institutions are somewhat special, especially banks, because such financial institutions have large teams of quantitative analysts then tend to be in the form of physicists or from institutions of quantitative scientists, some people with proper background in very relevant subjects, people who also know finance and a whole range of financial use cases, and people who are used to doing a lot of modelling. Some modelling skills is what is really important here. So I think this is what makes banks and financial institutions valuable consortium partners for hardware manufacturers and software developers.
Natalie Donovan	So unsurprisingly I think given the high barriers to entry that we've seen with something like quantum, in terms of both the level of resource needed and an expertise required, which I think Ben you touched on earlier, collaboration is really common and as we've heard that collaboration is between people with different skillsets and that's something we have seen not only with quantum but with lots of developing technologies like AI, for example, and also DLT.
Emily Bradley	Yes, and with your IP hat on Nat, it sounds like that might raise some quite complicated IP issues, is that right?
Natalie Donovan	Yeah, whenever you are looking at collaboration, there are issues to consider around ownership, and in particular potential joint ownership of any IP that's created, which can raise some interesting issues, and then of course there are issues around

	how that IP will be protected, how it can be used, etc. and I think the key really is to make sure that whatever collaboration arrangements you have in place, they need to clearly set out the ground rules for developing IP as part of that process. So, for example, the various parties need to be really clear both on what they are bringing into the arrangement, but also what they and others are able to do with any technology and IP that's used or developed as part of that arrangement. And I think it's something that a lot of organisations looking to develop technology like quantum are dealing with, and Alexei did mention some of these issues when we spoke to him.
Alexei Kondratyev	I guess it depends on the type of consorts and type of agreement that participants sign and the overall structure. A typical situation is when the background IP stays with consorts and partners and a new IP created so that the process of innovations and the process of a co-creation is then shared by consorts and partners. However there are many special cases, many exceptions, and I think every single collaboration, every single project is unique in this regard. But it also highlights importance of a proper legal support and expertise in escalated intellectual property so to patents, to patent applications, and so on.
Ben Kingsley	So obviously IP a very important issue to be thinking about whenever you're developing any new technology or solution with partner organisations. Another area that often comes up and that we find ourselves talking to clients about when we're involved in joint ventures and consortium development activities involving new tech is data and data privacy, data protection.
Alexei Kondratyev	I think exactly the same data privacy rules would apply and exactly the same regulations covered now around classical computing would apply to quantum computing. At the end of the day, quantum computing is just different way of performing computations, slightly different mathematics and algorithms on computations performed and just different type of hardware.
Natalie Donovan	I agree completely that the data protection rules are designed to be technology neutral and so all of the same rules as Alexei mentioned will apply regardless of whether the computations are performed on a classical or a quantum computer. I mean that said, we don't yet know what or even if quantum will raise any significant new DP compliance issues. We have heard a little bit in previous podcasts about potential security issues. We will need to see if quantum impacts issues like transparency and explainability and the kinds of things that are quite hot topics at the moment with something like AI. And if you simplify things, blockchain, for example, is just really a database, a type of ledger

	technology, but obviously the specific way that it works raises particular privacy issues. Similarly if you look at something like AI, that's another example of where a new technology has really needed some specific focus from the data regulator for it to be able to properly apply those existing rules to the new issues raised by that new technology.
Ben Kingsley	Yeah that seems fair comment Nat, so I do wonder about the regulatory approach to all of this and I think regulators inevitably will need to get up a curve if they have not already done so and we've seen that of course happening in the world of AI and distributive ledgers as you say, where certainly in the financial sector, there has been a lot of time and effort expended by the regulators to get their arms around those new technologies and some of the potential actual and potential emergent risks that they present, but I think that must be true for all regulators of industries that are going to have an interest in accessing quantum computing power surely?
Natalie Donovan	Yeah, it's definitely true to say we are increasingly seeing regulators work to understand the technology they are regulating. I have mentioned AI a couple of times and leaving aside that we now have AI specific regulation on the horizon at EU and possibly UK level, if you think about the ICO, the data regulator, it's run a number of projects around AI to ensure it's understanding the technology and applying those technology mutual laws to specific AI risks or, you know regulators are coming together to ensure they have got a joined up approach to digital regulation – the ICO, the CMA, OfCom – and I think now also the FCA are working together in something like the digital regulation co-operation forum, and as part of that they are committing to upskill knowledge in this area.
Emily Bradley	Yeah and focusing on the FCA is just one example, it's clearly an area which they are really focussing on at the moment. For example, within the past year, I am aware of the fact that they have been working with The Alan Turing Institute to get to grips with some of the complexities of AI and they also seem particularly interested in the impact of technology on customers, and how, when computers models cut consumer behaviour, for example, whether and how that produces fair outcomes for consumers, and you can see as quantum grows, this is going to be a real area of interest going forwards. And Alexei also agreed that regulatory input and upskilling is going to be crucial in the coming years.

Alexei Kondratyev	Quantum technology goes well beyond quantum computing. Quantum computing is just one out of many quantum technologies that enter our life right now. So probably the 21st Century is going to be the century of quantum technologies, in different shapes and forms. So yes, I think it will be very, very beneficial for authorities at different levels, regulators, business executives, policymakers, to improve understanding of quantum technologies.
Ben Kingsley	So I think although we are not yet seeing specific regulatory initiatives focusing on quantum technologies, quantum computing, certainly we can already see the direction of travel, based on the approach that regulators, and I'm thinking at the moment particularly about the FCA as a financial services sector regulator, the approach that the regulators are taking to adapt to new technologies and so for example, we can see with the FCA and the Banks of England's rules around operational resilience, a much greater focus on both the systemic risks and the institution's specific risks that dependencies on technologies or complex technologies, complex systems and processes, poses and one can see readily that a dependence, or at least a reliance on complex quantum computing modelling, for example, to run a balance sheet of a bank, would be an area of great focus and interest to the financial regulators. I would think also that, as has tended to be the case in the past, that you know industries themselves will want to start to develop their own standards once technologies such as this start to become a more common feature. I mean it must be likely, don't you think Nat, that we will see industry standards start to emerge.
Natalie Donovan	Yep, I think actually with standards there's a really interesting conversation to be had about the role of standards versus harder regulation if you like, and we've recently seen, for example, with the regulation of consumer smart devices, so Alexa etc., that initial work to develop standards is now being followed up with an increased focus on regulation. So I think for quantum it's going to be interesting to watch and see how the market develops in this regard and when we spoke to Alexei about standardisation, he was clear that there are standards emerging in the areas of algorithmic design, although he did mention that it was probably too early to demand any kind of particular standard when it came to physical hardware, given it's still being developed and it's not really clear yet if a dominant form of hardware is going to prevail.
Alexei Kondratyev	I think there is a lot of standardisation when we talk about algorithms, how quantum computing algorithms are designed, presented, explained, so I think there is some kind of emerging common language that allows people to present ideas in a

	standardised way. I think even the concept of a generally accepted notations very important here. When it comes to hardware, when it comes to physical systems on which computations can be run, it is probably too early to demand any particular standard because technologies are so different.
Ben Kingsley	So one thing that I have certainly taken from this discussion is that I think it is clear that quantum as a technology is not yet for everyone, albeit in some industries there is work going on and there will be some businesses that are regarding it as a priority for investment and exploration. It seems as though we are not yet really at a tipping point for use cases and, more importantly, for live fire adoption of the technology in a business environment, but I think I also take from our discussion that that tipping point could come along quite quickly, potentially we are hearing within a few years, but certainly on a mid-term horizon, it's a realistic prospect, and so I think it must make sense for businesses to do some forward planning, or at the very least, to have quantum on the agenda in procurement processes, and certainly for mid and longer term innovation strategies. We have also talked about the importance of bringing the regulators along and so if you're in a business operating in a regulated environment, I think having regard to the role and the interests of regulators at an early stage of developing and exploring this technology, will undoubtedly pay dividends in the longer term. So much promise from quantum computing – it's a topic that we're going to stay plugged into, and we will see how things develop across all of the industries that we are working with. We would be very interested to hear from clients, contacts that are either working in this area, or would like to get more involved in the area, so if that includes you, please do reach out to any or all of us, we would be delighted to talk more about this topic. For now though, let's wrap up and our thanks to Alexei Kondratyev of Standard Chartered Bank for providing us with insight and some food for thought in our discussions. Thanks also to Natalie and to Emily for your input into this podcast.
	Well that's a wrap on our short podcast series on quantum computing. We would obviously love to hear from you if this is a topic that you've been thinking about in the business context or if it's just something you would like to have an initial conversation around. We would be very happy to share our own thinking and to make connections to others working in the field. You can find the other two podcasts and further materials on this topic in our quantum hub at slaughterandmay.com/quantum-computing.